3. RANCH HAND VERSUS COMPARISON NONCAUSE-SPECIFIC ANALYSES

Survival contrasts were carried out between Ranch Hands and their C1-C5 matched Comparisons and between Ranch Hands and the entire population of Comparisons. Each analysis is presented with and without adjustment for the covariates of rank (officer, enlisted), occupation (flying, nonflying) and date of birth. All analyses are unadjusted for race due to the small proportion of blacks. A summary of the kinds of analyses carried out is shown in Table 10. Adjustments include date of birth (DOB), occupation (flying, nonflying), rank (officer, enlisted) and tour start date (tour date). Unadjusted contrasts of Ranch Hand and C1-C5 Comparisons reflect partial adjustment due to the matching of C1-C5 Comparisons to Ranch Hands on date of birth, rank, race and occupation. Such adjustment is simply indicated as "matching". Table 10 gives a summary of these methods.

TABLE 10

Analytical Method Summary

Contrast	Method	Adjustments
RH vs C1-C5	Two-sample survival curves	Matching
	Two-sample adjusted linear rank tests	DOB, race, rank, occupation, survival time
	Two-sample adjusted SMR	DOB, rank, occupation, tour date, survival time
	Two-sample unadjusted odds ratio	Matching
	Two-sample adjusted odds ratio	DOB, rank, occupation, tour date
RH vs All Comp	Two-sample survival curves	None
	Two-sample adjusted linear rank tests	DOB, rank, occupation survival time

TABLE 10 (Cont'd)

Analytical Method Summary

Contrast	Method	Adjustments
RH vs All Comp	Two-sample adjusted SMR	DOB, rank, occupation, tour date survival time
	Two-sample unadjusted odds ratio	None
	Two-sample adjusted odds ratio	DOB, rank, occupation, tour date
	One-sample unadjusted SMR	Tour date survival time
	One-sample adjusted SMR with fixed Comparison death rates	DOB, rank, occupation, tour date, calendar time survival time

The two-sample methods (linear rank tests, SMR [5] and odds ratio analyses) treat the Ranch Hands and Comparisons as samples from larger populations, even though they are actually populations rather than random samples. The adjusted SMR with fixed Comparison death rates [6] treats the Comparison population as a population rather than as a sample from a larger hypothetical population. This is the most appropriate method of analysis now that the entire Comparison population is available for reference with Ranch Hand mortality. The two-sample methods are repeated in the Ranch Hand versus All Comparison contrasts to ease the transition between this and previous mortality updates.

The Ejigou-McHugh odds ratio analysis [7] has been dropped and replaced by logistic regression because it has been recently shown [8] that the Ejigou-McHugh procedure may be viewed as a special case of conditional logistic regression [9] and because conditional logistic regression has been shown to yield the same results as logistic regression in these data. The Ejigou-McHugh method accommodates the matched design but does not otherwise adjust for the matching variables (race, rank, occupation and date of birth). Conditional logistic regression may be viewed as a generalization of the Ejigou-McHugh procedure in that it accommodates covariates and reduces to the Ejigou-McHugh procedure in matched designs with no additional covariates and when there is no mortality-by-covariate-by-group (Ranch Hand, Comparison) interaction. Additionally, conditional logistic regression allows the investigation of interactions whereas the Ejigou-McHugh procedure does not.

An attempt was made to replace the linear rank procedures with covariate adjusted contrasts via the proportional hazards model [10]. Chi-square tests of fit [11] and associated diagnostic plots were applied to assess modeling assumptions associated with the proportional hazards analysis. An application of the fully adjusted model to the Ranch Hand versus C1-C5 data failed because the date of birth covariate did not satisfy the proportional hazards assumption. The relevant diagnostic plot is shown in the Appendix. The proportional hazards assumption does hold, however, for group (Ranch Hand, Comparison), with or without adjustment for date of birth, hence the calculated logrank tests are appropriate summary statistics since they adjust for date of birth, rank and occupation via stratification.

Survival curves were calculated and plotted in Figures 1 through 10. In these plots, the Ranch Hand curve is a power of the respective Comparison curve, the power being the odds ratio estimated via application of the method of maximum likelihood from the proportional hazards model. Figures 1 through 5 show adjusted Ranch Hand and C1-C5 Comparison survival curves of the total cohort and in each of the four marginal strata: officers, enlisted, flying personnel and nonflying personnel. Figures 6 through 10 show the corresponding plots for Ranch Hands versus all Comparisons. In every plot, survival is measured from the start of the qualifying tour so the ordinate is interpreted as the proportion surviving since start of tour. The corresponding plots for survival measured from birth rather than from tour start date are shown in the Appendix. Also shown in the Appendix are nonparametric (Kaplan-Meier) plots [12] with survival measured from tour start date and from date of birth.

Figure 1

Survival Curve Estimates
All Ranch Hands and C1-C5 Comparisons
Survival from Start of Tour

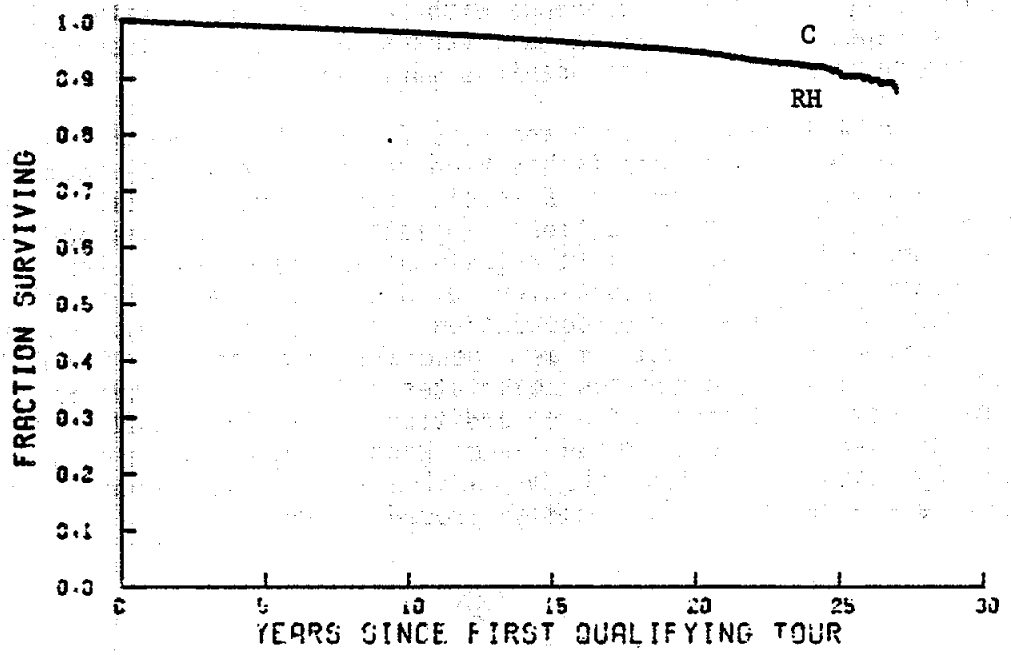


Figure 2

Survival Curve Estimates
Ranch Hand and C1-C5 Comparison Officers
Survival from Start of Tour

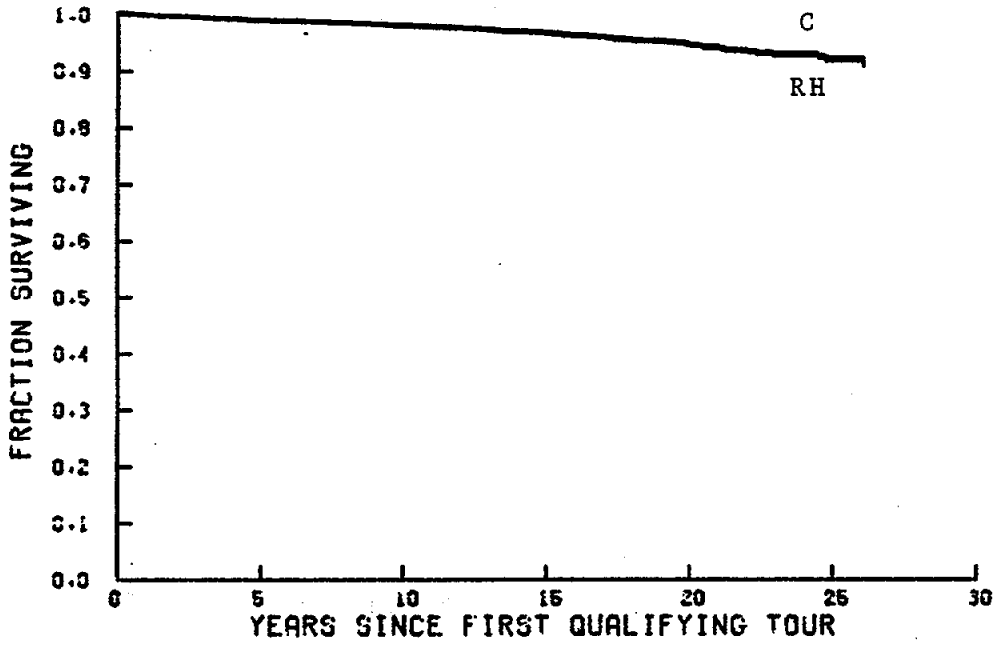


Figure 3

Survival Curve Estimates
Ranch Hand and C1-C5 Comparison Enlisted Personnel
Survival from Start of Tour

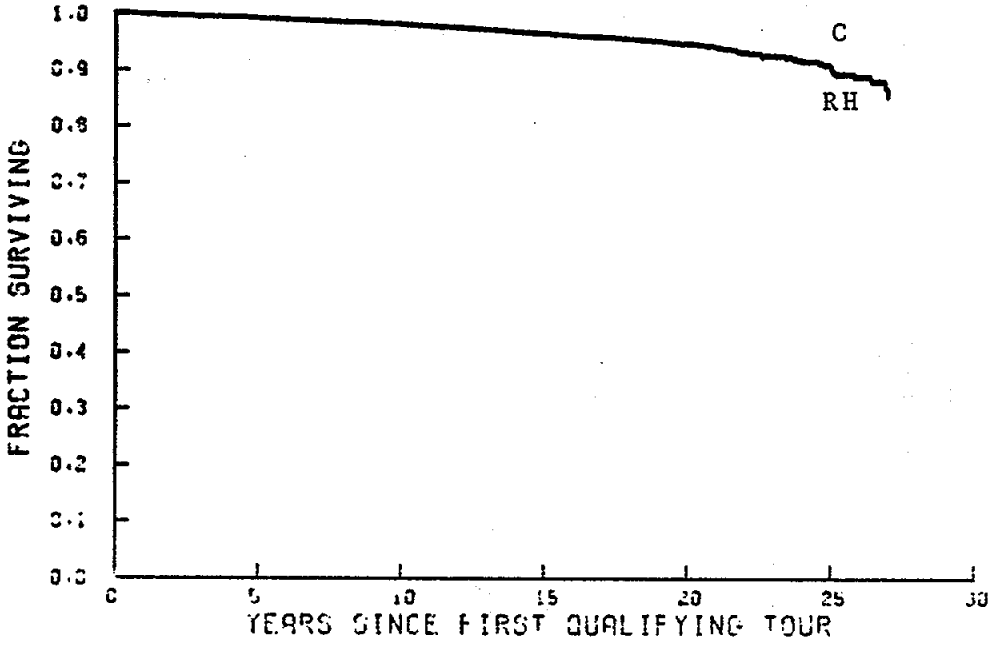


Figure 4

Survival Curve Estimates
Ranch Hand and C1-C5 Comparison Flyers
Survival from Start of Tour

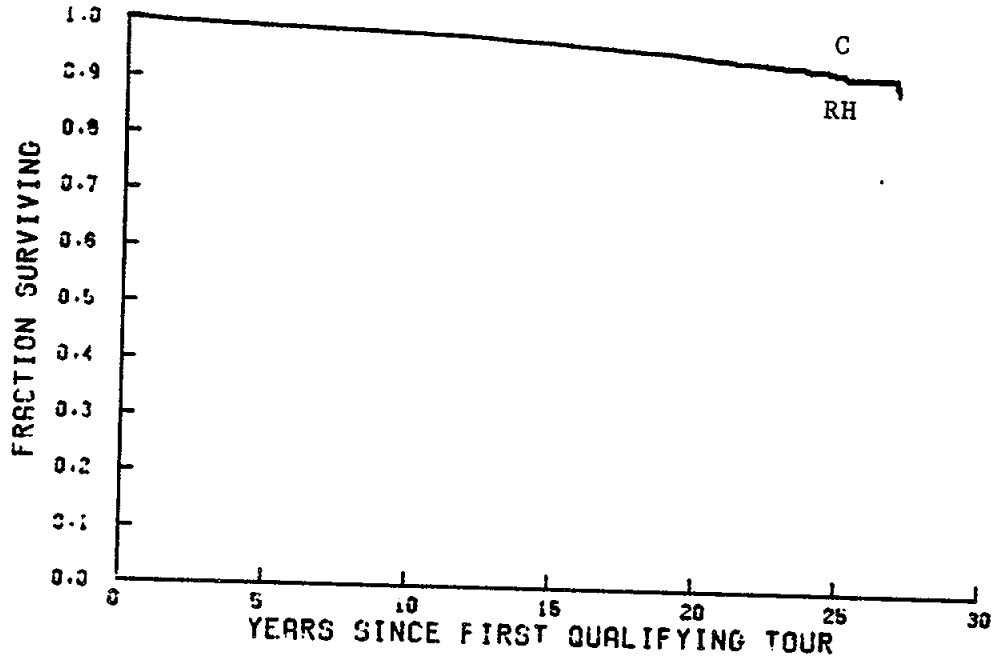


Figure 5

Survival Curve Estimates
Ranch Hands and C1-C5 Comparison Nonflyers
Survival from Start of Tour

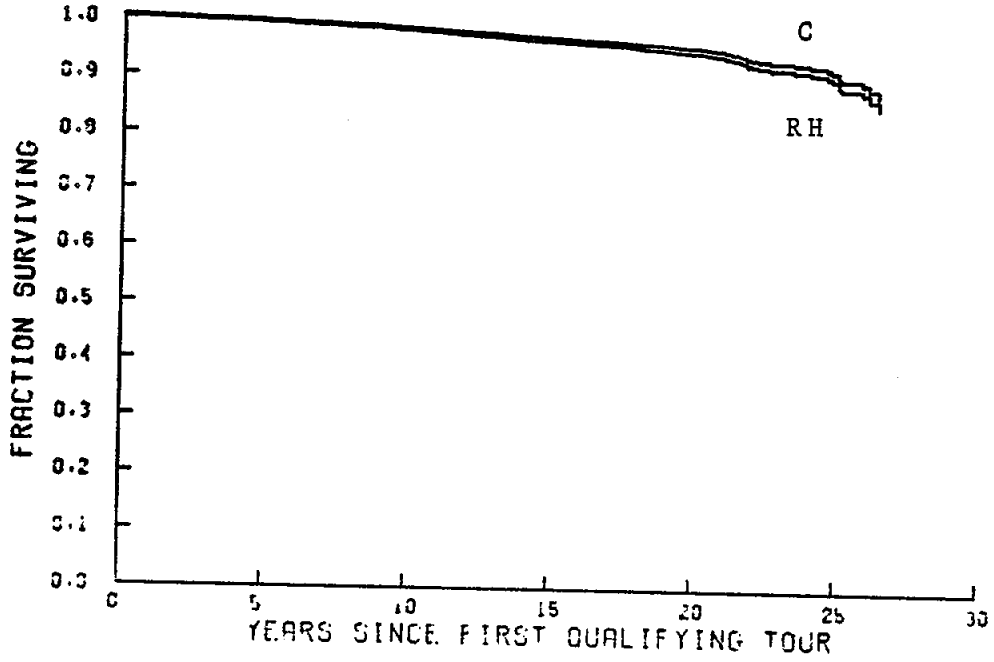


Figure 6

Survival Curve Estimates
All Ranch Hands and All Comparisons
Survival from Start of Tour

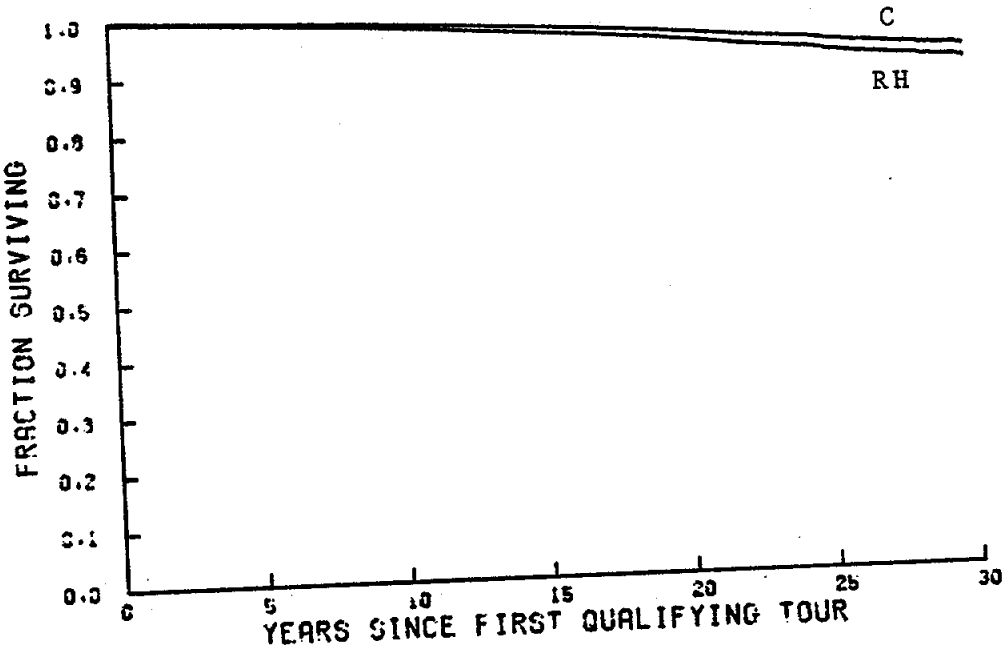


Figure 7

Survival Curve Estimates
Ranch Hand and All Comparison Officers
Survival from Start of Tour

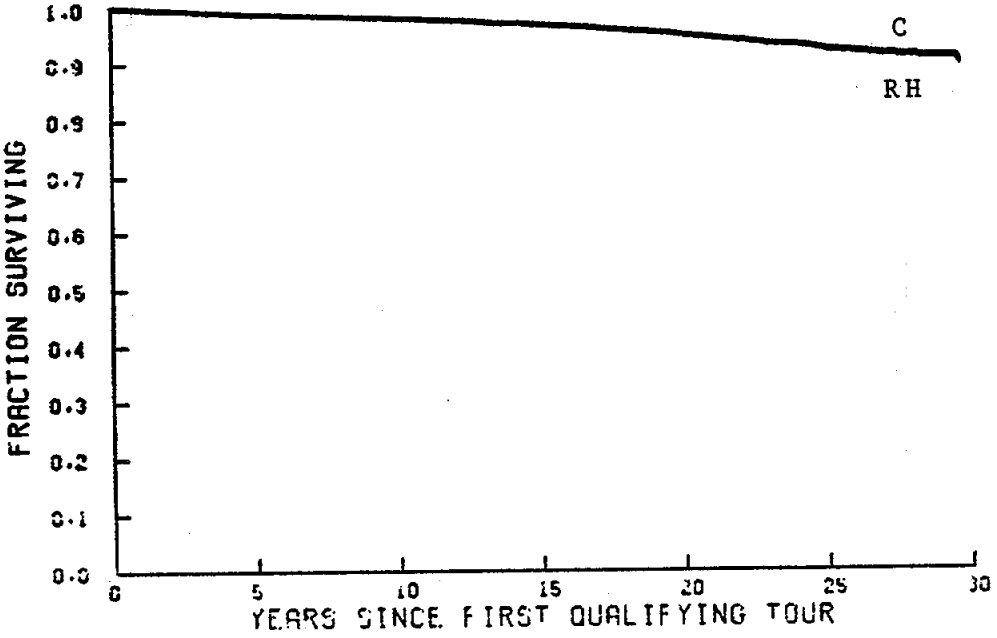


Figure 8

Survival Curve Estimates
Ranch Hand and All Comparison Enlisted Personnel
Survival from Start of Tour

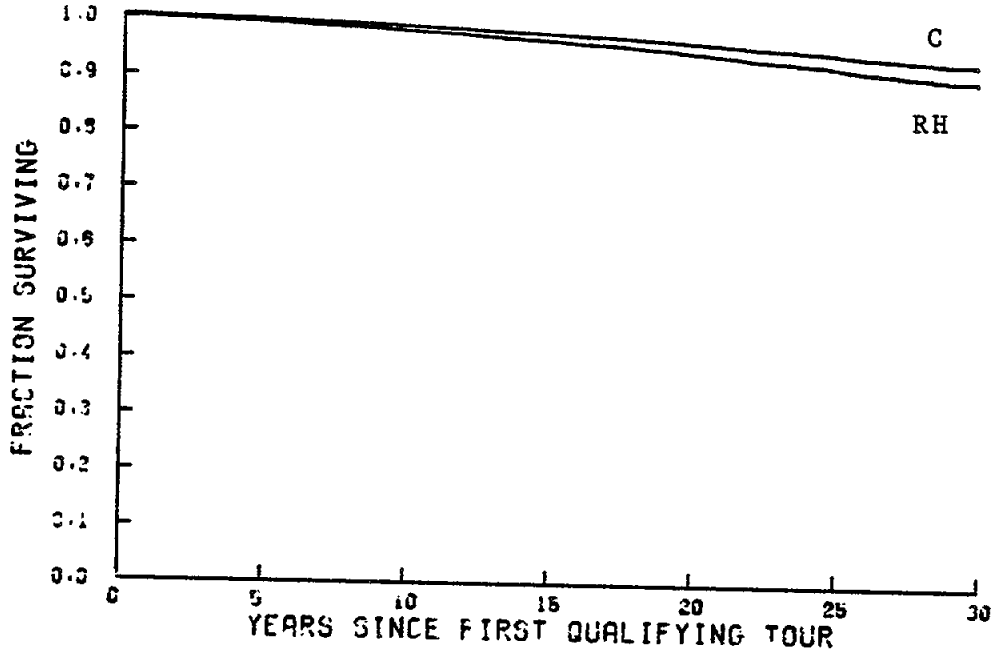


Figure 9

Survival Curve Estimates
Ranch Hand and All Comparison Flyers
Survival from Start of Tour

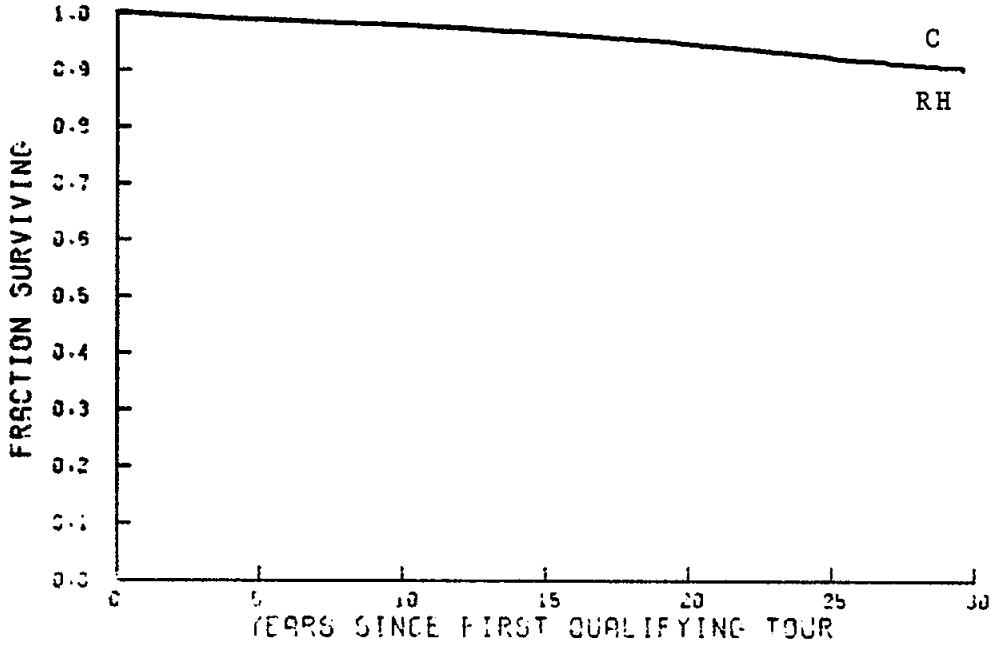
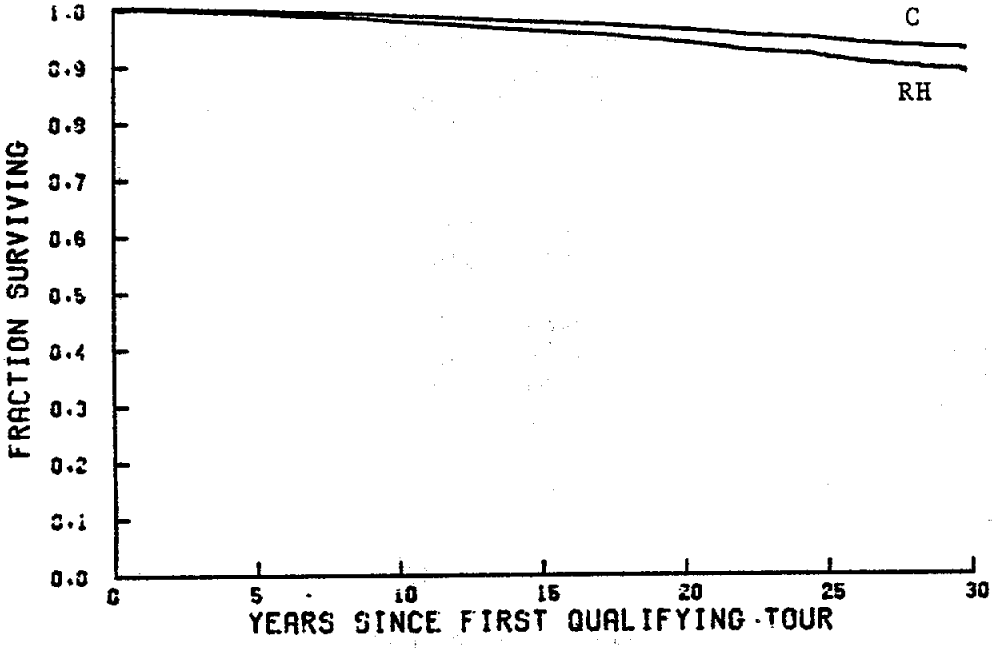


Figure 10

Survival Curve Estimates
Ranch Hand and All Comparison Nonflyers
Survival from Start of Tour



The survival curves are so close together in Figures 1 through 4 and 7 and 9 that there appears to be only a single curve in each of these figures. This occurred because the Ranch Hand curve is the Comparison curve raised to the Ranch Hand versus C1-C5 odds ratio power and these odds ratios are nearly equal to unity. In general, the Ranch Hand and C1-C5 Comparison curves are closer together than the Ranch Hand and all Comparison curves because matching provides better adjustment than stratification.

The linear rank procedures (logrank and Wilcoxon tests) contrasting Ranch Hand with C1-C5 mortality and all Comparison mortality are shown in Table 11 with survival measured from tour start date. The corresponding results for survival measured from date of birth are shown in Table 12.

TABLE 11

Logrank and Wilcoxon Tests Contrasting
Ranch Hand and Comparison Mortality with
Survival Measured from Tour Start Date

	C1-C5 Comparison				All Comparison			
Group	Logrank Test	P-value	Wilcoxon Test	P-value	Logrank Test	P-value	Wilcoxon Test	P-value
Officer	0.31	0.75	0.26	0.80	0.21	0.83	0.16	0.87
Enlisted	0.07	0.94	0.11	0.91	0.89	0.37	0.96	0.34
Flying	-0.34	0.74	-0.40	0.69	-0.48	0.63	-0.52	0.60
Nonflying	0.68	0.49	0.74	0.46	1.73	0.08	1.79	0.07
All	0.29	0.83	0.22	0.83	0.73	0.47	0.74	0.46

TABLE 12

Logrank and Wilcoxon Tests Contrasting
Ranch Hand and Comparison Mortality with
Survival Measured from Date of Birth

	C1-C5 Comparison				All Comparison			
Group	Logrank Test	P-value	Wilcoxon Test	P-value	Logrank Test	P-value	Wilcoxon Test	P-value
Officer	0.00	1.00	-0.02	0.99	-0.35	0.73	-0.37	0.71
Enlisted	-0.26	0.79	-0.25	0.80	0.22	0.83	0.26	0.80
Flying	-0.66	0.51	-0.70	0.48	-1.08	0.28	-1.12	0.26
Nonflying	0.34	0.74	0.37	0.71	1.09	0.28	1.13	0.26
All	-0.21	0.83	-0.22	0.82	-0.18	0.85	-0.18	0.86

Table 11 suggests that nonflying personnel in the Ranch Hand group are dying sooner than their matched Comparisons (logrank = 0.68) when survival is measured from tour start date, but that the difference is not statistically significant (P=0.49). The same contrast for Ranch Hands versus all Comparisons is borderline significant (logrank = 1.73, P=0.08). The negative values of the logrank and Wilcoxon statistics for flyers in Table 11 indicate that Ranch Hands in this stratum are living longer than the Comparisons, but this is easily attributed to chance (P=0.74). The corresponding results in Table 12, for survival measured from date of birth, are generally nonsignificant with some reversals relative to Table 9. The results in Table 11 are more appropriate than those in Table 12, however. Table 12 is shown only for comparison with previous updates.

Unadjusted odds ratio estimates, confidence intervals and P-values, contrasting Ranch Hand and C1-C5 Comparison mortality overall and within each of the four marginal strata, are shown in Table 13. The corresponding results for Ranch Hand versus all Comparisons are shown in Table 14. The unadjusted odds ratio estimate for the Ranch Hand versus all Comparison contrast was carried out via the two-sample odds ratio estimate and also via the one-sample approach [6] treating the Comparison population as fixed, in which the odds ratio is the SMR, the ratio of the observed to the expected number of deaths.

TABLE 13

Unadjusted Odds Ratio Estimates Contrasting
Ranch Hand with C1-C5 Mortality

Stratum	Odds Ratio	95% C I	P-value
Officer	1.01	(0.65, 1.56)	0.97
Enlisted	0.96	(0.69, 1.32)	0.78
Flying	0.89	(0.62, 1.28)	0.54
Nonflying	1.07	(0.74, 1.54)	0.71
All	0.97	(0.75, 1.26)	0.84

TABLE 14

Unadjusted Odds Ratio Estimates Contrasting
Ranch Hand and All Comparison Mortality,
with Person-years Computed from Tour Start Date

	Two-sample Procedure			One-sample Procedure			
Stratum	Odds Ratio	95% C I	P-value	Obs	Exp	SMR	P-value
Officer	0.92	(0.61, 1.38)	0.68	26	26.5	0.98	0.92
Enlisted	1.17	(0.87, 1.59)	0.30	48	38.4	1.24	0.12
Flying	0.88	(0.62, 1.24)	0.46	37	39.2	0.94	0.72
Nonflying	1.30	(0.92, 1.84)	0.13	37	25.8	1.43	0.03
All	1.08	(0.85, 1.38)	0.52	74	62.7	1.18	0.15

Table 13 demonstrates a near equivalence of Ranch Hand and C1-C5 mortality without adjustment for covariates. The corresponding results in Table 14 are very similar with the exception that the Ranch Hand nonflying personnel are experiencing significantly more deaths than nonflying personnel in the Comparison population (SMR=1.43, P=0.03) in the unadjusted one-sample analysis.

In the corresponding adjusted two-sample analyses, odds ratios were determined by stepwise logistic regression with group (Ranch Hand, Comparison), date of birth, rank (officer, enlisted), occupation (flying, nonflying), tour start date and all pairwise products in the model. Each adjusted analysis was carried out with date of birth and tour start date entered as continuous variables and again with date of birth and tour date dichotomized as prior to or after 1 January 1935 and 1 October 1968. The cut point for date of birth was chosen to allow investigation of interactions discovered in the 1984 update; the cutpoint for tour start date is the median tour date in the combined Ranch Hand and Comparison database. Adjusted two-sample contrasts of Ranch Hand and C1-C5 mortality are summarized in Table 15. The corresponding summary of the two-sample Ranch Hand and all Comparison mortality is shown in Table 16.

TABLE 15

Adjusted Two-sample Odds Ratio Estimates Contrasting Ranch Hand with C1-C5 Mortality

Odds Ratio	95% C I	P-value	Covariates and Interactions (P-value)
Dichotomized Date of Birth and Tour Start Dates			
1.00	(0.88, 1.14)	0.93	Rank (P<0.01) Occupation (0.34) Tour start (P<0.01) Date of birth (P<0.01) Occ by DOB (P<0.01)
Continuous Date of Birth and Tour Start Dates			
1.00	(0.87, 1.14)	0.96	Rank (P<0.01) Tour start (0.12) Date of birth (P<0.01)

Date of birth and tour start date are uncorrelated in these data (r-square = 0.0016), a fortunate circumstance that precludes concern about multicollinearity. The lack of correlation is most likely due to the rapid turnover of personnel during the war.

TABLE 16

Adjusted Two-sample Odds Ratio Estimates Contrasting
Ranch Hands with All Comparisons

Dichotomized Date of Birth and Tour Start Dates

Odds Ratio	95% C I	P-value	Covariates and Interactions (P-value)
****	**********	****	Rank (P<0.01) Occupation (0.01) Tour start (0.37) Date of birth (P<0.01) Group by tour (0.01) Rank by tour (0.14) Occ by tour (P<0.01) Occ by DOB (P<0.01) Tour by DOB (P<0.01)

Continuous Date of Birth and Tour Start Dates

1.00	(0.88, 1.13)	0.96	Rank (P<0.01) Occupation (0.01) Tour start (0.17) Date of birth (P<0.01) Tour by DOB (0.03)

The group by tour by survival interaction in the discrete analysis is due to the change in the group by survival odds ratio with tour date (early, late). The presence of an interaction involving group (Ranch Hand, Comparison) precluded the specification of an odds ratio, confidence interval and P-values; these statistics are replaced by asterisks in Table 16. For veterans with early tours, the Mantel-Haenszel adjusted group by survival odds ratio is 1.10 and for late tours the adjusted odds ratio is 0.93. It is notable that the same interaction is not significant in the continuous analysis. This suggests that the just described interaction is spurious. In particular, if tour date is trichotomized to early, middle and late tours, the corresponding Mantel-Haenszel adjusted group by survival odds ratios are 0.90 for early tours, 1.23 for middle tours and 0.84 for late tours. This interaction remains unexplained at this time.

The two-sample [5] internally adjusted SMR analysis compares the mortality of two groups with adjustment for year of birth. These analyses are carried out as in previous updates, within each of the four rank and occupational strata as well as on the whole group. Survival is measured from tour start date in these analyses. The corresponding analyses with survival measured from birth are shown in the Appendix. Tables 17 through 21 show the two-sample SMR analyses for Ranch Hand versus C1-C5 mortality and Tables 22 through 26 show the corresponding analyses for Ranch Hand versus all Comparison mortality contrasts.

TABLE 17

Two-sample Standardized Mortality Ratios
Ranch Hand and C1-C5 Comparison Officers
Survival from Start of Tour

SMR= 1.03 (P= 0.87)

Birth Year	Ranch Hand Number At Risk	Ranch Hand Number Dead	Ranch Hand Person-years	Ranch Hand Rate Per 1000 P Y	C1-C5 Comparison Number At Risk	C1-C5 Comparison Number Dead	C1-C5 Comparison Person-years	C1-C5 Comparison Rate Per 1000 P Y
1905-1919	9	3	152	19.76	44	8	868	9.21
1920-1924	32	2	651	3.07	160	21	3217	6.53
1925-1929	43	3	867	3.46	289	22	5909	3.72
1930-1934	151	8	3108	2.57	645	39	13401	2.91
1935-1939	96	4	1969	2.03	467	20	9822	2.04
1940-1944	91	4	1725	2.32	505	12	9813	1.22
1945-1954	45	2	777	2.57	190	5	3373	1.48
Total	467	26	9248	2.81	2300	127	46403	2.74

TABLE 18

Two-sample Standardized Mortality Ratios
Ranch Hand and C1-C5 Comparison Enlisted Personnel
Survival from Start of Tour

SMR= 0.99 (P= 0.93)

Birth Year	Ranch Hand Number At Risk	Ranch Hand Number Dead	Ranch Hand Person-years	Ranch Hand Rate Per 1000 P Y	C1-C5 Comparison Number At Risk	C1-C5 Comparison Number Dead	C1-C5 Comparison Person-years	C1-C5 Comparison Rate Per 1000 P Y
1905-1914	4	2	77	26.00	12	4	278	14.41
1915-1919	9	2	185	10.80	53	14	1108	12.64
1920-1924	16	3	333	9.01	80	18	1677	10.73
1925-1929	41	4	851	4.70	215	35	4448	7.87
1930-1934	154	17	3030	5.61	755	70	15709	4.46
1935-1939	117	5	2368	2.11	577	35	11992	2.92
1940-1944	121	4	2486	1.61	616	24	12676	1.89
1945-1954	332	11	6386	1.72	1642	49	32002	1.53
Total	794	48	15716	3.05	3950	249	79888	3.12

TABLE 19

Two-sample Standardized Mortality Ratios
Ranch Hand and C1-C5 Comparison Flyers
Survival from Start of Tour

SMR= 0.92 (P= 0.63)

	Ranch Hand				C1-C5 Comparison			
Birth Year	Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y	Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y
1915-1919	9	4	136	29.34	45	10	865	11.56
1920-1924	35	2	720	2.78	175	25	3512	7.12
1925-1929	53	3	1079	2.78	353	29	7237	4.01
1930-1934	219	15	4435	3.38	972	71	19980	3.55
1935-1939	146	6	2954	2.03	712	36	14737	2.44
1940-1944	122	5	2380	2.10	668	23	13068	1.76
1945-1954	64	2	1144	1.75	286	10	5213	1.92
Total	648	37	12848	2.88	3211	204	64612	3.16

TABLE 20

Two-sample Standardized Mortality Ratios
Ranch Hand and C1-C5 Comparison Nonflyers
Survival from Start of Tour

SMR= 1.09 (P= 0.63)

	Ranch Hand				C1-C5 Comparison			
Birth Year	Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y	Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y
1905-1914	5	2	99	20.27	14	5	325	15.38
1915-1919	8	1	179	5.59	50	11	1064	10.34
1920-1924	13	3	264	11.36	65	14	1382	10.13
1925-1929	31	4	639	6.26	151	28	3120	8.98
1930-1934	86	10	1703	5.87	428	38	9129	4.16
1935-1939	67	3	1383	2.17	332	19	7076	2.68
1940-1944	90	3	1831	1.64	453	13	9421	1.38
1945-1954	313	11	6019	1.83	1546	44	30162	1.46
Total	613	37	12116	3.05	3039	172	61679	2.79

TABLE 21

Two-sample Standardized Mortality Ratios
All Ranch Hand and C1-C5 Comparison
Survival from Start of Tour

SMR= 1.00 (P= 0.99)

Birth Year	Ranch Hand Number At Risk	Ranch Hand Number Dead	Ranch Hand Person-years	Ranch Hand Rate Per 1000 P Y	C1-C5 Comparison Number At Risk	C1-C5 Comparison Number Dead	C1-C5 Comparison Person-years	C1-C5 Comparison Rate Per 1000 P Y
1905-1914	5	2	99	20.27	14	5	325	15.38
1915-1919	17	5	315	15.86	95	21	1929	10.89
1920-1924	48	5	984	5.08	240	39	4894	7.97
1925-1929	84	7	1718	4.08	504	57	10357	5.50
1930-1934	305	25	6138	4.07	1400	109	29110	3.74
1935-1939	213	9	4337	2.08	1044	55	21814	2.52
1940-1944	212	8	4211	1.90	1121	36	22489	1.60
1945-1954	377	13	7163	1.81	1832	54	35375	1.53
Total	1261	74	24964	2.96	6250	376	126291	2.98

TABLE 22

Two-sample Standardized Mortality Ratios
All Ranch Hand and All Comparison Officers
Survival from Start of Tour

SMR= 1.01 (P= 0.96)

Birth Year	Ranch Hand Number At Risk	Ranch Hand Number Dead	Ranch Hand Person-years	Ranch Hand Rate Per 1000 P Y	C1-C5 Comparison Number At Risk	C1-C5 Comparison Number Dead	C1-C5 Comparison Person-years	C1-C5 Comparison Rate Per 1000 P Y
1905-1919	9	3	152	19.76	148	31	3095	10.02
1920-1924	32	2	651	3.07	573	76	12464	6.10
1925-1929	43	3	867	3.46	512	53	10469	5.06
1930-1934	151	8	3108	2.57	1221	73	25731	2.84
1935-1939	96	4	1969	2.03	1121	44	24354	1.81
1940-1944	91	4	1725	2.32	1563	47	32990	1.42
1945-1954	45	2	777	2.57	393	10	7386	1.35
Total	467	26	9248	2.81	5531	334	116489	2.87

TABLE 23

Two-sample Standardized Mortality Ratios
All Ranch Hand and All Comparison Enlisted
Survival from Start of Tour

SMR= 1.11 (P= 0.48)

Birth Year	Ranch Hand Number At Risk	Ranch Hand Number Dead	Ranch Hand Person-years	Ranch Hand Rate Per 1000 P Y	C1-C5 Comparison Number At Risk	C1-C5 Comparison Number Dead	C1-C5 Comparison Person-years	C1-C5 Comparison Rate Per 1000 P Y
1905-1914	4	2	77	26.00	18	8	413	19.37
1915-1919	9	2	185	10.80	105	34	2167	15.69
1920-1924	16	3	333	9.01	274	61	5820	10.48
1925-1929	41	4	851	4.70	657	97	14196	6.83
1930-1934	154	17	3030	5.61	1921	168	41450	4.05
1935-1939	117	5	2368	2.11	1701	101	37164	2.72
1940-1944	121	4	2486	1.61	2425	70	53911	1.30
1945-1954	332	11	6386	1.72	6469	166	142115	1.17
Total	794	48	15716	3.05	13570	705	297237	2.37

TABLE 24

Two-sample Standardized Mortality Ratios
All Ranch Hand and All Comparison Flyers
Survival from Start of Tour

SMR= 0.90 (P= 0.54)

Birth Year	Ranch Hand Number At Risk	Ranch Hand Number Dead	Ranch Hand Person-years	Ranch Hand Rate Per 1000 P Y	C1-C5 Comparison Number At Risk	C1-C5 Comparison Number Dead	C1-C5 Comparison Person-years	C1-C5 Comparison Rate Per 1000 P Y
1905-1919	9	4	136	29.34	140	35	2867	12.21
1920-1924	35	2	720	2.78	576	85	12361	6.88
1925-1929	53	3	1079	2.78	669	75	13799	5.44
1930-1934	219	15	4435	3.38	1790	136	37196	3.66
1935-1939	146	6	2954	2.03	1630	78	34818	2.24
1940-1944	122	5	2380	2.10	1928	70	40462	1.73
1945-1954	64	2	1144	1.75	1345	42	29094	1.44
Total	648	37	12848	2.88	8078	521	170596	3.05

TABLE 25

Two-sample Standardized Mortality Ratios
All Ranch Hand and Comparison Nonflyers
Survival from Start of Tour

SMR= 1.28 (P= 0.15)

Birth Year	Ranch Hand Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y	C1-C5 Comparison Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y
1905-1914	5	2	99	20.27	18	8	414	19.33
1915-1919	8	1	179	5.59	113	30	2394	12.53
1920-1924	13	3	264	11.36	271	52	5923	8.78
1925-1929	31	4	639	6.26	500	75	10867	6.90
1930-1934	86	10	1703	5.87	1352	105	29985	3.50
1935-1939	67	3	1383	2.17	1192	67	26701	2.51
1940-1944	90	3	1831	1.64	2060	47	46440	1.01
1945-1954	313	11	6019	1.83	5517	134	120406	1.11
Total	613	37	12116	3.05	11023	518	243130	2.13

TABLE 26

Two-sample Standardized Mortality Ratios
All Ranch Hand and All Comparison
Survival from Start of Tour

SMR= 1.06 (P= 0.63)

Birth Year	Ranch Hand Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y	C1-C5 Comparison Number At Risk	Number Dead	Person-years	Rate Per 1000 P Y
1905-1914	5	2	99	20.27	22	9	512	17.59
1915-1919	17	5	315	15.86	249	64	5163	12.39
1920-1924	48	5	984	5.08	847	137	18284	7.49
1925-1929	84	7	1718	4.08	1169	150	24666	6.08
1930-1934	305	25	6138	4.07	3142	241	67181	3.59
1935-1939	213	9	4337	2.08	2822	145	61519	2.36
1940-1944	212	8	4211	1.90	3988	117	86902	1.35
1945-1954	377	13	7163	1.81	6862	176	149500	1.18
Total	1261	74	24964	2.96	19101	1039	413726	2.51

Adjusted one-sample analyses, summarized in Table 27, assess Ranch Hand mortality relative to all Comparison death rates in 5 year age and calendar time strata within each of the four rank and occupational strata (officer, enlisted, flying, nonflying) and over the entire Ranch Hand cohort with adjustment for rank and occupation.

TABLE 27

Adjusted One-sample Ranch Hand Contrasts with All Comparisons

Officers

SMR=0.95, 95% C I : (0.59,1.32), P=0.79

Birth Year	Number At Risk	Person-years	Number Dead	Adjusted Expected Deaths
1910-1914	1	22	0	0.22
1915-1919	8	130	3	1.26
1920-1924	32	651	2	4.79
1925-1929	43	867	3	3.92
1930-1934	151	3108	8	9.83
1935-1939	96	1969	4	3.81
1940-1944	91	1725	4	2.53
1945-1949	45	777	2	1.01
Total	467	9249	26	27.37

Enlisted

SMR=1.05 95% C I : (0.75,1.35), P=0.73

Birth Year	Number At Risk	Person-years	Number Dead	Adjusted Expected Deaths
1910-1914	4	77	2	1.60
1915-1919	9	185	2	2.94
1920-1924	16	333	3	3.80
1925-1929	41	851	4	5.69
1930-1934	154	3030	17	12.82
1935-1939	117	2368	5	7.16
1940-1944	121	2486	4	4.05
1945-1949	321	6188	11	7.77
1950-1954	11	197	0	0.24
Total	794	15715	48	45.63

TABLE 27 (Cont'd)

Adjusted One-sample Ranch Hand Contrasts with All Comparison

Flyers

SMR=0.86, 95% C I : (0.58,1.13), P=0.35

Birth Year	Number At Risk	Person-years	Number Dead	Adjusted Expected Deaths
1915-1919	9	136	4	1.63
1920-1924	35	720	2	5.99
1925-1929	53	1079	3	5.83
1930-1934	219	4435	15	16.63
1935-1939	146	2954	6	7.04
1940-1944	122	2379	5	4.17
1945-1949	64	1144	2	1.90
Total	648	12847	37	43.19

Nonflyers

SMR=1.23, 95% C I : (0.83,1.63), P=0.21

Birth Year	Number At Risk	Person-years	Number Dead	Adjusted Expected Deaths
1910-1914	5	99	2	1.36
1915-1919	8	179	1	2.33
1920-1924	13	264	3	2.63
1925-1929	31	639	4	3.72
1930-1934	86	1703	10	6.66
1935-1939	67	1383	3	3.87
1940-1944	90	1831	3	2.65
1945-1949	302	5822	11	6.64
1950-1954	11	197	0	0.24
Total	613	12117	37	30.11

TABLE 27 (Cont'd)

Adjusted One-sample Ranch Hand Contrasts with All Comparison

All Ranch Hands

SMR=1.01, 95% C I : (0.80, 1.26), P=0.95

Birth Year	Number At Risk	Person-years	Number Dead	Adjusted Expected Deaths
1905-1914	5	99	2	1.24
1915-1919	17	315	5	3.79
1920-1924	48	984	5	8.88
1925-1929	84	1718	7	9.60
1930-1934	305	6138	25	23.46
1935-1939	213	4337	9	11.09
1940-1944	212	4211	8	6.47
1945-1949	366	6966	13	8.80
1950-1954	11	197	0	0.24
Total	1261	24965	74	73.57

In the analysis on all Ranch Hands, summarized in the last panel of Table 27, there was no survival by rank by occupation interaction (P=0.48) and the Ranch Hand versus all Comparison mortality contrast did not vary significantly with rank (P=0.53) or occupation (P=0.12).

The previous one and two sample adjusted contrasts (Tables 15 through 27), although fully adjusted for rank, occupation and year of birth, may not detect very recent trends. For example, inspection of Tables 5 and 6 and Appendix Tables 1, 2 and 3 suggests that Ranch Hand flyers are experiencing unusually high death rates relative to all Comparisons during 1986 and 1987. Therefore, chi-square tests for trend [6] were applied to all strata and all Ranch Hands to assess the presence of post-1983 trends in the SMR. These analyses were carried out twice, first with each of the years 1983 through 1987 separately contributing to the statistic and again with 1983 through 1985 collapsed to a single stratum and 1986 and 1987 collapsed to a second stratum. The second analysis with two strata was carried out after noting the increased SMR in flyers during 1986 and 1987. Table 28 shows the results for Ranch Hands versus C1-C5 Comparisons and Table 29 shows the results for Ranch Hands contrasted with all Comparisons. All of these analyses are conditioned on survival to 1 January 1983 and, due to data sparseness, are not adjusted for date of birth. The tests are two-tailed and will therefore detect upward or downward trends in the SMR. Test results for detecting upward trends in the SMR may be derived from these results by dividing the P-value by 2 when the data indicate an increasing trend and replacing the P-value by 1.00 when the data indicate a decreasing trend. These data were not assessed relative to the Air Force exposure index due to sparseness.

TABLE 28

Ranch Hand Mortality
Five Year Trend Analysis vs C1-C5 Comparison

Flying Officers

Chi-square (single year)=3.74 P=0.05
Chi-square (83-85,86-87)=7.54 P=0.01

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	0	0.00	0.61	0.00
1984	1	2.35	1.43	0.70
1985	1	2.35	2.05	0.49
1986	5	11.84	0.82	6.12
1987	4	9.54	2.03	1.97

Enlisted Flyers

Chi-square (single year)=0.34 P=0.56
Chi-square (83-85,86-87)=0.14 P=0.71

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	1	5.03	1.22	0.82
1984	0	0.00	1.22	0.00
1985	1	5.07	0.82	1.22
1986	1	5.08	1.64	0.61
1987	1	5.11	0.62	1.62

All Flyers

Chi-square (single year)=4.62 P=0.03
Chi-square (83-85,86-87)=6.50 P=0.01

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	1	1.60	1.84	0.54
1984	1	1.60	2.66	0.38
1985	2	3.21	2.87	0.70
1986	6	9.70	2.45	2.44
1987	5	8.13	2.65	1.89

TABLE 28 (Cont'd)

Ranch Hand Mortality
Five Year Trend Analysis vs C1-C5 Comparison

Nonflying Officers

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	0	0.00	0.00	0.00
1984	0	0.00	0.00	0.00
1985	0	0.00	0.00	0.00
1986	0	0.00	0.00	0.00
1987	0	0.00	0.63	0.00

Nonflying Enlisted Personnel

Chi-square (single year)=0.26 P=0.61
Chi-square (83-85,86-87)=0.01 P=0.92

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	2	3.58	1.20	1.67
1984	0	0.00	1.79	0.00
1985	2	3.59	2.80	0.71
1986	3	5.42	2.60	1.15
1987	1	1.81	2.80	0.36

All Nonflyers

Chi-square (single year)=0.46 P=0.50
Chi-square (83-85,86-87)=0.00 P=0.96

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	2	3.43	1.20	1.67
1984	0	0.00	1.80	0.00
1985	2	3.44	2.81	0.71
1986	3	5.19	2.60	1.15
1987	1	1.74	3.41	0.29

TABLE 28 (Cont'd)

Ranch Hand Mortality
Five Year Trend Analysis vs C1-C5 Comparison

All Officers

Chi-square (single year)=2.44 P=0.12
Chi-square (83-85,86-87)=5.73 P=0.02

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	0	0.00	0.61	0.00
1984	1	2.22	1.43	0.70
1985	1	2.22	2.05	0.49
1986	5	11.18	0.82	6.12
1987	4	9.01	2.65	1.51

All Enlisted Personnel

Chi-square (single year)=0.01 P=0.94
Chi-square (83-85,86-87)=0.08 P=0.77

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	3	3.96	2.40	1.25
1984	0	0.00	3.01	0.00
1985	3	3.98	3.62	0.83
1986	4	5.33	4.23	0.95
1987	2	2.68	3.42	0.58

All Personnel

Chi-square (single year)=1.41 P=0.24
Chi-square (83-85,86-87)=3.48 P=0.06

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	3	2.48	3.03	0.99
1984	1	0.83	4.44	0.22
1985	4	3.32	5.67	0.71
1986	9	7.52	5.06	1.78
1987	6	5.04	6.07	0.99

TABLE 29

Ranch Hand Mortality
Five Year Trend Analysis vs All Comparison

Flying Officers

Chi-square (single year)=4.89 P=0.03
Chi-square (83-85,86-87)=6.10 P=0.01

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	0	0.00	1.87	0.00
1984	1	2.35	1.70	0.59
1985	1	2.35	1.45	0.69
1986	5	11.84	1.79	2.80
1987	4	9.54	2.29	1.75

Enlisted Flyers

Chi-square (single year)=0.16 P=0.69
Chi-square (83-85,86-87)=0.09 P=0.76

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	1	5.03	1.03	0.97
1984	0	0.00	0.89	0.00
1985	1	5.07	0.89	1.13
1986	1	5.08	1.34	0.75
1987	1	5.11	0.74	1.35

All Flyers

Chi-square (single year)=4.75 P=0.03
Chi-square (83-85,86-87)=5.27 P=0.02

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	1	1.60	2.92	0.34
1984	1	1.60	2.60	0.38
1985	2	3.21	2.36	0.85
1986	6	9.70	3.17	1.89
1987	5	8.13	3.00	1.67

TABLE 29 (Cont'd)

Ranch Hand Mortality
Five Year Trend Analysis vs All Comparison

Nonflying Officers

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	0	0.00	0.00	0.00
1984	0	0.00	0.09	0.00
1985	0	0.00	0.09	0.00
1986	0	0.00	0.18	0.00
1987	0	0.00	0.37	0.00

Nonflying Enlisted Personnel

Chi-square (single year)=0.01 P=0.93
Chi-square (83-85,86-87)=0.21 P=0.65

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	2	3.58	1.24	1.62
1984	0	0.00	1.88	0.00
1985	2	3.59	2.21	0.90
1986	3	5.42	1.88	1.59
1987	1	1.81	1.99	0.50

All Nonflyers

Chi-square (single year)=0.03 P=0.86
Chi-square (83-85,86-87)=0.13 P=0.71

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	2	3.43	1.26	1.59
1984	0	0.00	1.97	0.00
1985	2	3.44	2.30	0.87
1986	3	5.19	2.03	1.48
1987	1	1.74	2.24	0.45

TABLE 29 (Cont'd)

Ranch Hand Mortality
Five Year Trend Analysis vs All Comparison

All Officers

Chi-square (single year)=4.22 P=0.04
Chi-square (83-85,86-87)=5.38 P=0.02

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	0	0.00	1.88	0.00
1984	1	2.22	1.79	0.56
1985	1	2.22	1.54	0.65
1986	5	11.18	1.96	2.55
1987	4	9.01	2.64	1.51

All Enlisted Personnel

Chi-square (single year)=0.02 P=0.89
Chi-square (83-85,86-87)=0.30 P=0.58

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	3	3.96	2.14	1.40
1984	0	0.00	2.72	0.00
1985	3	3.98	3.08	0.97
1986	4	5.33	3.07	1.30
1987	2	2.68	2.72	0.73

All Personnel

Chi-square (single year)=2.70 P=0.10
Chi-square (83-85,86-87)=4.31 P=0.04

Year	Number Dead	Rate Per 1000 Person Years	Expected Deaths	SMR
1983	3	2.48	3.88	0.77
1984	1	0.83	4.48	0.22
1985	4	3.32	4.68	0.85
1986	9	7.52	5.01	1.80
1987	6	5.04	5.13	1.17

In the Ranch Hand versus all Comparison trend analyses (Table 29), the increased SMR's specific to the calendar years 1986 and 1987 for flyers shown in Tables 5 and 6 are seen to produce an increasing trend from 1983 through 1987, with the respective SMR's being 0.34, 0.38, 0.85, 1.89, and 1.67. This trend is statistically significant (two tailed P=0.03, one tailed P=0.015) and is due to unusually low Ranch Hand death rates prior to 1986 and elevated Ranch Hand rates during 1986 and 1987. Inspection of Table 29 suggests that the trend within the flyers is due to an increasing trend in the SMR within the flying officer stratum, with no trend apparent within the enlisted flyer stratum. No trends are apparent or are detected in the nonflying or enlisted strata. The significant increasing trends in the officer stratum (two tailed P=0.04, one tailed P=0.02) and all personnel (two tailed P=0.04, one tailed P=0.02) is due to the trend within the flying officer stratum. The significant trend seen in the last panel of Table 29, for all Ranch Hands is due to the elevated SMR's specific to 1986 and 1987 (two tailed P=0.04, one tailed P=0.02) and is attributable to the trend within with flying officers. The Ranch Hand versus C1-C5 Comparison results are similar.

Inspection of Tables 35 and 36 and Appendix Tables 4, 5 and 6, which show counts of deaths during the calendar years 1983 through 1987 by cause, rank and occupation, shows that of the 5 flying officer Ranch Hand deaths during 1986, 3 were due to malignant neoplasm (SMR=3.92), 1 was a circulatory system death (SMR=1.68) and 1 was due to unknown causes (SMR not defined). Of the 4 deaths within the Ranch Hand flying officers occurring during 1987, 1 was accidental (SMR=6.00), 1 was due to a malignant neoplasm (SMR=0.98) and 2 were due to diseases of the circulatory system (SMR=2.62). The single Ranch Hand flying officer death during 1984 was due to circulatory system disease (SMR=2.35) and the single death occurring during 1985 was due to a malignant neoplasm (SMR=2.35). These patterns suggest that the observed trend may be attributed to increased numbers of Ranch Hand malignant neoplasm and circulatory deaths. Inspection of Tables 48, 49, 51 and 52 and Appendix Tables 7, 8, 9, 11, 12 and 13 shows that the observed Ranch Hand malignant neoplasm deaths during 1983 through 1987 among flyers or flying officers are not restricted to a particular anatomic site or morphological type.

With regard to exposures to herbicides and the contaminant TCDD (dioxin), an increasing trend within Ranch Hand flying officers is not expected because TCDD assay results in living Ranch Hands show that Ranch Hand flying officers were among the least exposed of all Ranch Hand personnel, with the heaviest exposures occurring in nonflying enlisted personnel.

The observed statistically significant increasing trend in the SMR among flying officers is of concern and emphasizes the importance of continued mortality surveillance. However, it appears to be due to recent elevations in Ranch Hand circulatory and malignant neoplasm death rates with no apparent pattern by anatomic site or morphology among those deaths due to malignant neoplasm. If herbicide exposure were having a direct effect on malignant disease, one would anticipate a clustering by site or type of cancer. Thus the implication of these observations is as yet unclear. Further, the trend is not expected relative to known TCDD body burdens among living Ranch Hands currently being assayed. The finding therefore remains unexplained at this time. The analyses shown in Tables 28 and 29 will be repeated in the next mortality report.

A lexis diagram of Ranch Hand officer deaths by age and calendar year period is shown in Figure 11. Follow-up time is indicated for each subject with a straight line beginning at his age and the beginning of his first qualifying tour and ending at his age at 31 December 1987 if he was still alive at that time. Follow-up lines for deceased subjects end with a box at the subjects age at death and date of death. The corresponding diagram without the follow-up lines is shown in Figure 12. Lexis diagrams for enlisted, flying and nonflying personnel, without follow-up lines, are shown in Figures 13 through 15.

Lexis diagrams provide another view of the data that permits a visual assessment of mortality clustering with respect to age and calendar time. A strong latency effect, for example, might be revealed by a cluster of deaths approximately 20 years after entry into follow-up. No such clusters are apparent in these data.

Figure 11

Lexis Diagram
Ranch Hand Officers

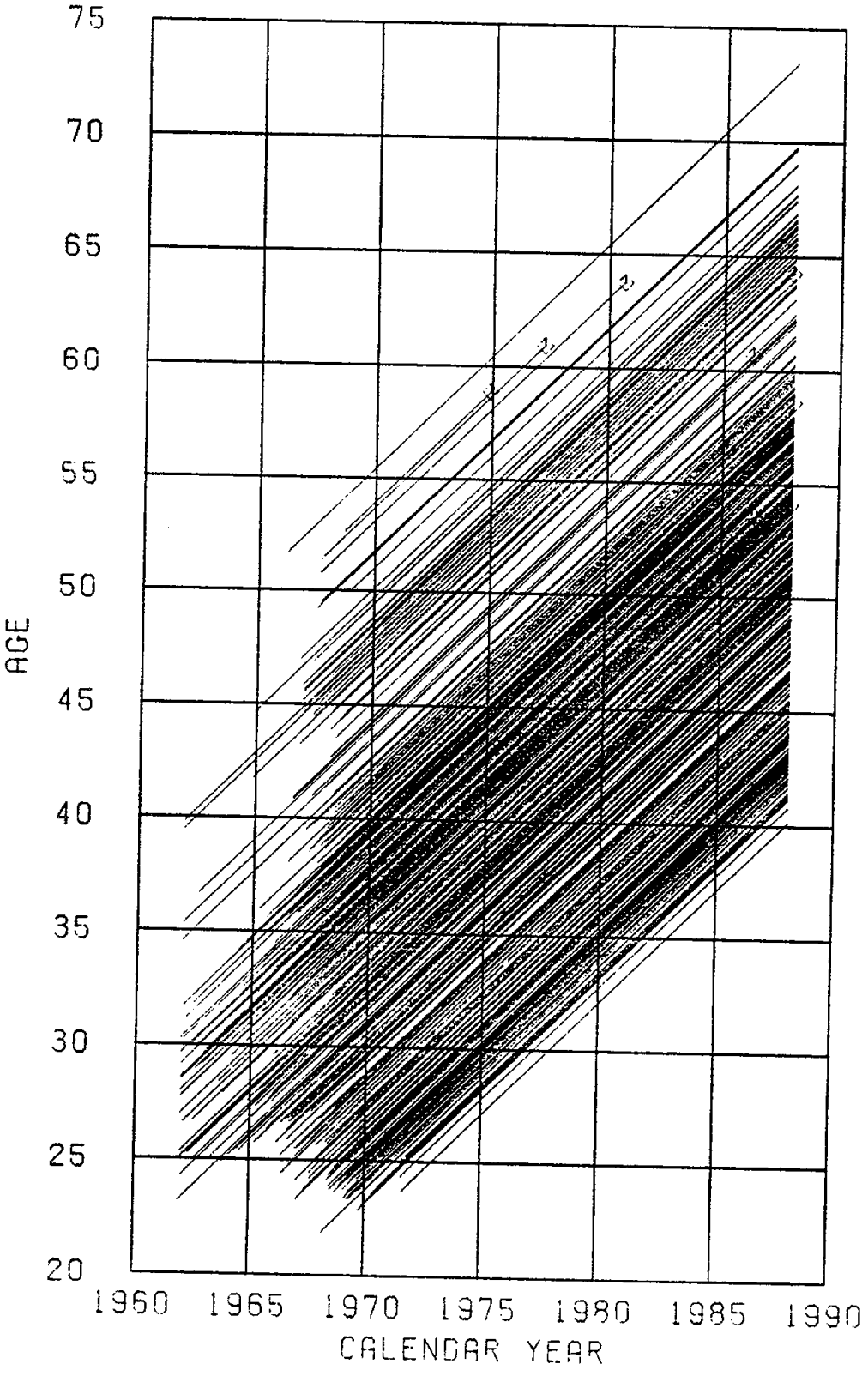


Figure 12

Lexis Diagram
R nch Hand Officers

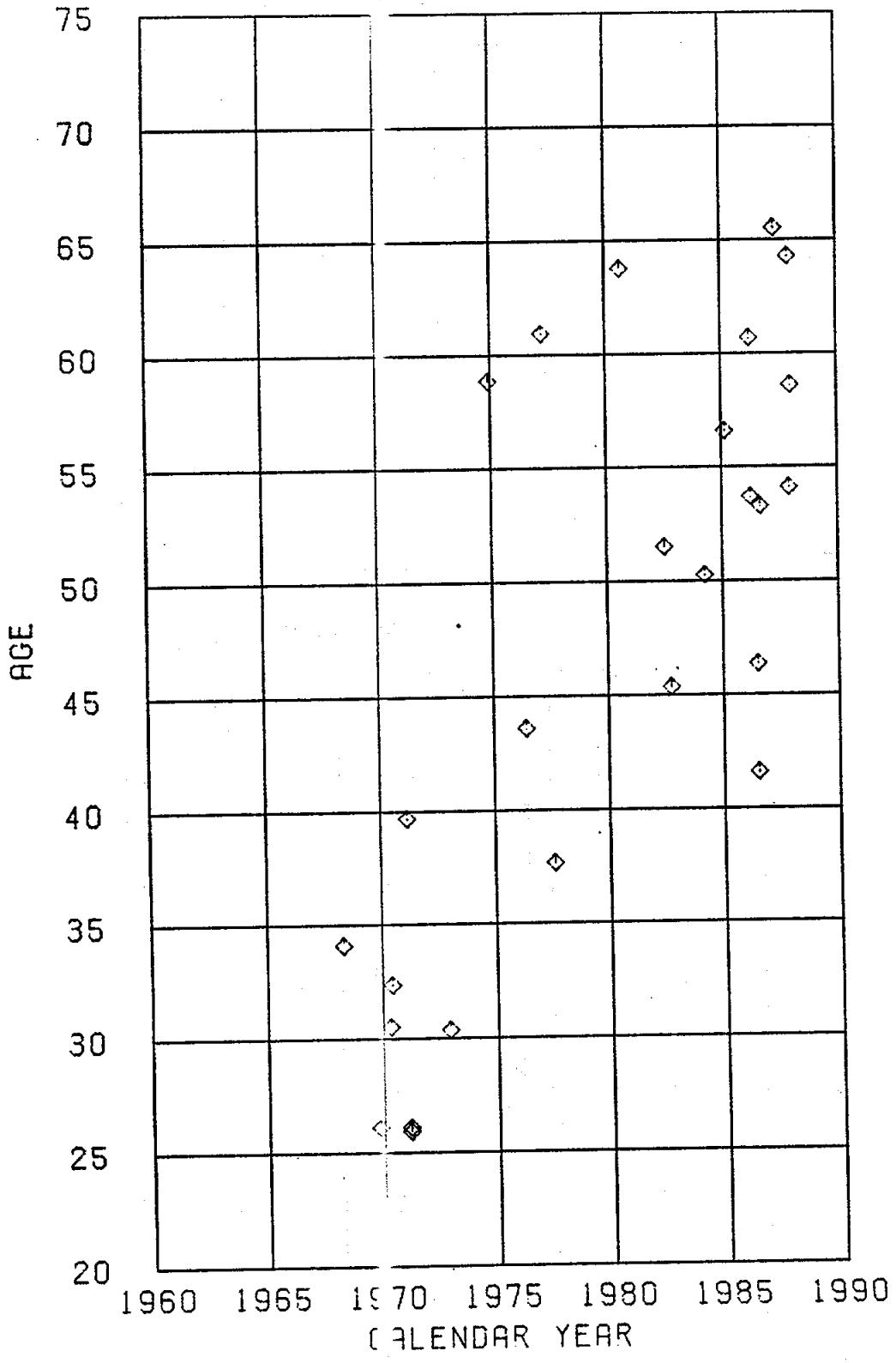


Figure 13

Lexis Diagram
Ranch Hand Enlisted Personnel

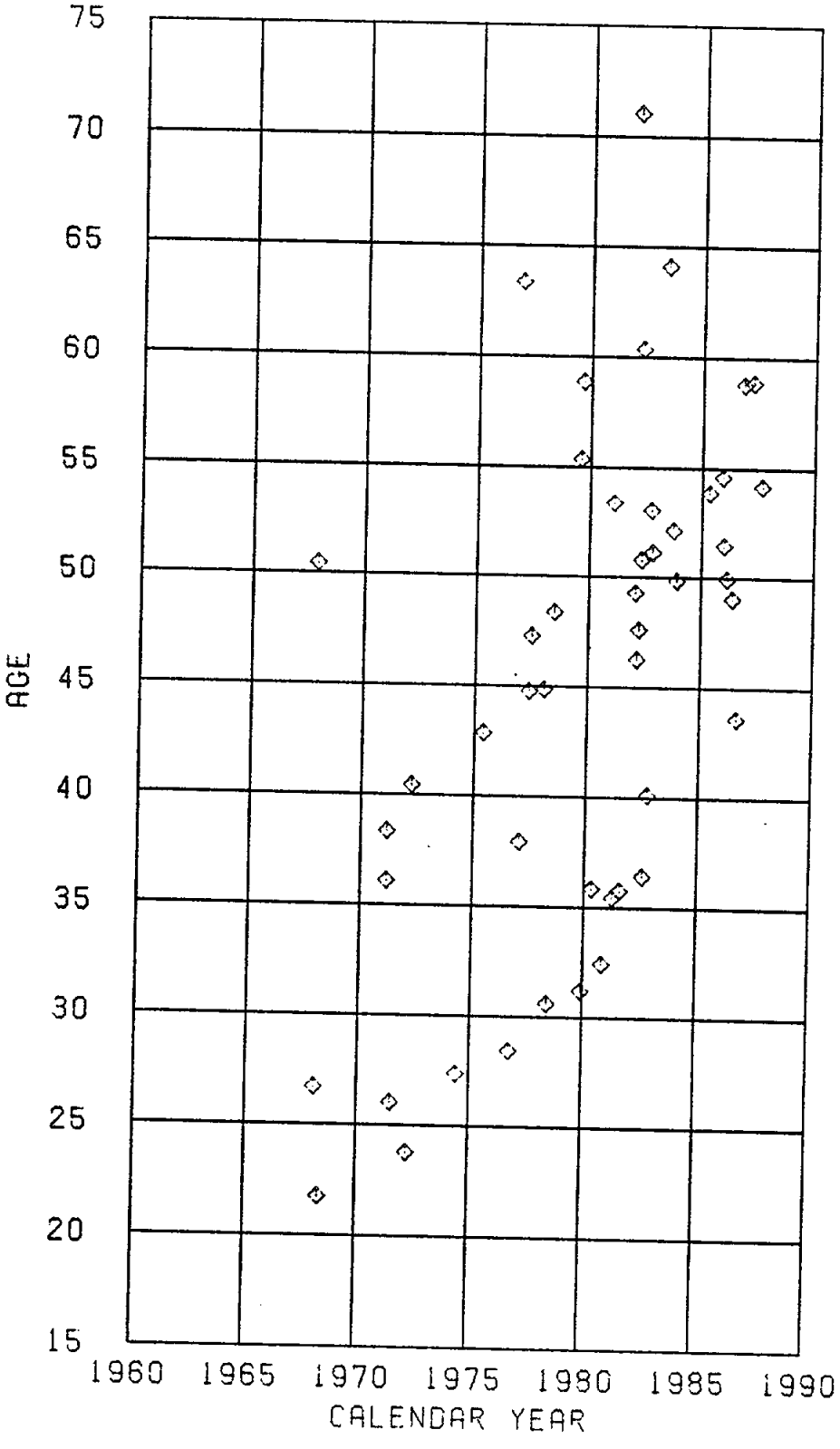


Figure 14

Lexis Diagram
Ranch Hand Flyers

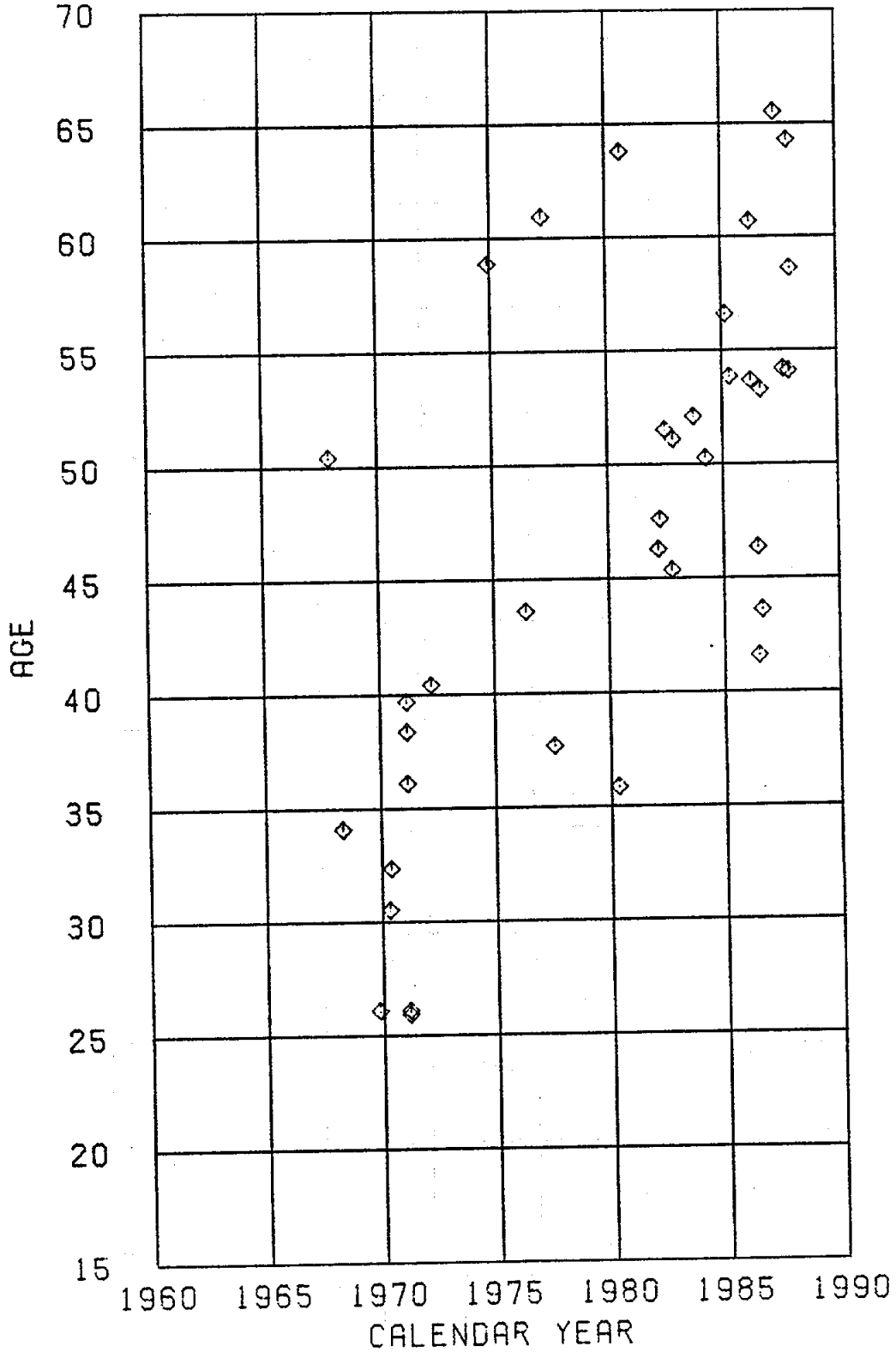
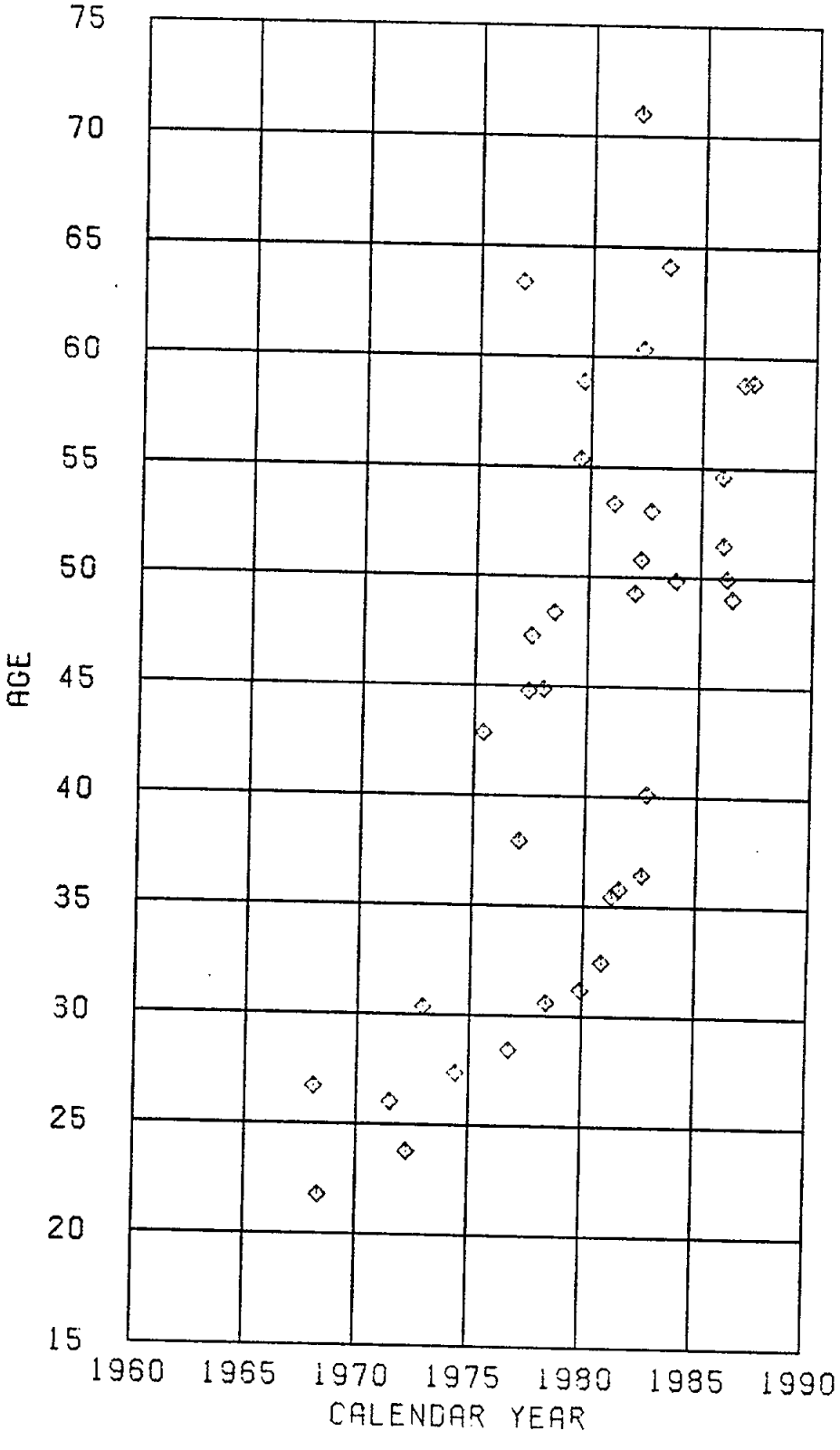


Figure 15

Lexis Diagram
Ranch Hand Nonflyers



A statistically significant group (Ranch Hand, C1-C5 Comparison) by survival (dead, alive) by date of birth (<1935, >1935) by rank (officer, enlisted) interaction was described in the 1984 update. This interaction was not detected in any of the adjusted two-sample procedures applied to either Ranch Hand versus C1-C5 Comparison contrasts or to Ranch Hand versus all Comparison contrasts in this report. Current data relevant to the group by survival by date of birth by rank association for Ranch Hands and C1-C5 Comparisons is shown in Table 30.

TABLE 30

Survival by Group, Date of Birth and Rank for Ranch Hands and C1-C5 Comparisons

Rank	Birth	Group	Number Dead	Number Alive	Total	Rate (%)	Relative Risk
Enlisted	<1935	Ranch Hand	28	196	224	12.5	0.99
		Comparison	141	974	1115	12.6	
		Total	169	1170	1339		
	>1935	Ranch Hand	20	550	570	3.5	0.92
		Comparison	108	2727	2835	3.8	
		Total	128	3277	3405		
Officer	<1935	Ranch Hand	16	219	235	6.8	0.86
		Comparison	90	1048	1138	7.9	
		Total	106	1267	1373		
	>1935	Ranch Hand	10	222	232	4.3	1.35
		Comparison	37	1125	1162	3.2	
		Total	47	1347	1394		

The group by survival by date of birth by rank association is not significant in these data with (P=0.30) or without (P=0.34) adjustment for occupation and tour start date.

The corresponding data for the Ranch Hand versus all Comparison contrast is shown in Table 31.

TABLE 31

Survival by Group, Date of Birth and Rank for Ranch Hands and All Comparisons

Rank	Birth	Group	Number Dead	Number Alive	Total	Rate (%)	Relative Risk
Enlisted	<1935	Ranch Hand	25	165	190	13.1	1.02
		Comparison	327	2210	2537	12.8	
		Total	352	2375	2727		
	>1935	Ranch Hand	23	581	604	3.8	1.11
		Comparison	378	10655	11033	3.4	
		Total	401	11236	11637		
Officer	<1935	Ranch Hand	15	196	211	7.1	0.70
		Comparison	223	1973	2196	10.1	
		Total	238	2169	2407		
	>1935	Ranch Hand	11	245	256	4.3	1.29
		Comparison	111	3224	3335	3.3	
		Total	122	3469	3591		

The group by survival by date of birth by rank association is not statistically significant in these data with (P=0.34) or without (P=0.28) adjustment for occupation and tour start date.

A statistically significant group by survival-to-age-35 by rank association in Ranch Hand and C1-C5 Comparison data was also described in the 1984 update. The same association was investigated with current data in both Ranch Hand versus C1-C5 Comparisons and Ranch Hand versus all Comparisons. The same group by survival-to-age-35 by rank interaction is borderline significant in current data on Ranch Hand versus C1-C5 mortality (P=0.05). The data relevant to the Ranch Hand versus C1-C5 contrast on survival to age 35 is shown in Table 32.

TABLE 32

Ranch Hand versus C1-C5 Comparisons
Group, Survival to Age 35, Rank

Survival to Age 35

Rank	Group	Number Dead	Number Alive	Total	Rate (%)	Relative Risk
Officer	Ranch Hand	7	460	467	1.5	2.30
	Comparison	15	2285	2300	0.6	
	Total	22	2745	2767		
Enlisted	Ranch Hand	9	785	794	1.1	0.72
	Comparison	62	3888	3950	1.6	
	Total	71	4673	4744		

This interaction appears to be due to an excess of Ranch Hand officer deaths before the age of 35. The observed number of Ranch Hand officer deaths before the age of 35 is 7 and the expected number is 3. These small numbers limit the meaning of these findings. Six of the seven Ranch Hand officer deaths before age 35 were due to accidents and one was a suicide. Of the 15 C1-C5 Comparison officer deaths before age 35, 13 were due to accidents, one was due to disease and one was a suicide. Of the 9 Ranch Hand enlisted deaths before the age of 35, 7 were due to accidents, one was a suicide and one was a homicide. Of the 62 C1-C5 Comparison enlisted deaths before the age of 35, 39 were due to accidents, 14 were disease related, 1 was a homicide and 8 were suicides. When these analyses were restricted to accidental deaths before the age of 35, the group by survival by rank association is not statistically significant (P=0.13). The same interaction is not statistically significant when suicide before the age of 35 is considered (P=0.31). Taken together, these results suggest that the observed interaction is spurious rather than attributable to herbicide exposure. The same analysis revealed no significant group by survival-to-age-35 by rank association when all Comparisons are analyzed (P=0.27). The relevant data is shown in Table 33.

TABLE 33

Ranch Hand versus All Comparisons
Group, Survival to Age 35, Rank

Survival to Age 35

Rank	Group	Number Dead	Number Alive	Total	Rate (%)	Relative Risk
Officer	Ranch Hand	7	460	467	2.0	1.54
	Comparison	54	5477	5531	1.0	
	Total	61	5937	5998		
Enlisted	Ranch Hand	9	785	794	1.0	0.86
	Comparison	178	13392	13570	1.0	
	Total	187	14177	14364		

When survival to age 35 is replaced by accidental death before the age of 35, the group by survival by rank association is not statistically significant (P=0.48). These results lend further weight to the conclusion that the group by survival to age 35 by rank association seen in Ranch Hand versus C1-C5 data was indeed spurious.